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Motor Vehicle Rollover and Static Stability: An Exposure Study

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ABSTRACT

Objectives. This study examined vehicle rollovers in terms of site-specific exposure and speeds of vehicles of varying stability.

Methods. Fifty-one rollover sites in two states were visited at the same time of day and day of week as the rollover. A sample of vehicles moving in the same direction as the rollover were observed, and vehicle-specific data were obtained from identification numbers.

Results. Low stability, exacerbated by the addition of passengers, increased the risk of rollover. Speed was not correlated with stability and is not a confounder.

Conclusions. Rollovers could be substantially reduced if motor vehicles were manufactured with a static stability of 1.2 or greater. (*Am J Public Health.* 1997;87;839–841)

Introduction

Some 8000 motor vehicle occupants die in rollovers in the United States each year.[1] In Utah during 1989 and 1990, 75% of the motor vehicle–related spinal cord injuries occurred in rollovers.[2] Rollover can be reduced by increasing stability—track width divided by twice the height of center of gravity (T/2H).[3]

Rollover is more frequent in vehicles of lower stability[4–9] and is exacerbated by increased passenger load that raises the center of gravity.[10] Reduction in rollover as T/2H increases is substantial when T/2H is less than 1.2, but there is little or no correlation above that point.[11] Since the speed of the vehicle is not known in a majority of cases, and is often a questionable estimate when it is recorded on crash reports, control for speed has not been adequate in previous research, although some of the other factors, such as driver age, may be partial proxies for speeding. If vehicles of lower stability are driven at higher speeds than more stable vehicles, their higher rollover rates could occur at least in part because of systematic differences in speed.

This study estimates the odds of rollover relative to stability given the presence of different types of vehicles, passenger loads, and drivers in the same environment (exposure), and it reports correlation of speeds of vehicles at rollover sites in relation to vehicle and driver characteristics.

Methods

Rollovers that occurred within 50 miles of New Haven, Conn, and Tuba City, Ariz, during April and early May of 1995 were identified from police reports. The study covered cars, pickup trucks, vans, and utility vehicles that rolled over during daylight hours, were registered in the state of the rollover, had a known T/2H, and were not in collisions with other vehicles.

To obtain exposure data, the site of the crash was visited at the same time of day and day of week that the rollover occurred. From 15 minutes prior to time of the crash to 15 minutes afterward, vehicles that passed the site traveling in the same direction as the vehicle that rolled over were observed. Their speeds were measured by a conventional police radar gun. Only free-moving vehicles, those not impeded by traffic in front of them, were included. The gender and approximate age of the driver, the number of visible occupants, and the license tag number were recorded. When an observation was completed, the next free-moving vehicle that appeared after a minute was observed.

Vehicle identification numbers were obtained from the Departments of Motor Vehicles and decoded into specific makes, models, and model years. T/2H, wheelbase, curb weight, and horsepower of the vehicles were obtained from lists in the dockets of the National Highway Traffic Safety Administration and in published sources. As was the case for vehicles that rolled over, if T/2H was unknown, the observations were excluded. Observations were done only at sites where the T/2H of the rolled-over vehicle was available.

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TABLE 1—Rollover and Same-Site Exposure Vehicles by Stability (T/2H): A Study of Rollovers within 50 Miles of New Haven, Conn, and Tuba City, Ariz, April and Early May of 1995

	T/2H			
	<1.10	1.10–1.19	1.20 and Over	Total
Rollover vehicles				
No.	8	10	33	51
%	15.69	19.61	64.71	...
Exposure vehicles				
No.	32	74	448	554
%	5.78	13.36	80.87	...
Total vehicles				
No.	40	84	481	605
%	6.61	13.88	79.50	100.00

Note. T/2H = track width divided by twice the height of the center of gravity.

TABLE 2—Stepwise Logistic Regression of Rollover vs Comparison Vehicles at the Same Times and Places: Analysis of Variables Removed by Fast Backward Elimination

Variable Removed	Chi-Squared	*P* > Chi-Squared
Weight/horsepower	0.0000	0.9988
T/2H if >1.2, otherwise 1.2	0.1762	0.6729
Age	0.7896	0.3742
Average T/2H	1.4372	0.2306

Note. Model Fit: $-2 \log L\ \chi^2 = 25.9$, $df = 4$ ($P = .0001$).

TABLE 3—Stepwise Logistic Regression of Rollover vs Comparison Vehicles at the Same Times and Places: Analysis of Maximum Likelihood Estimates

Variable	Parameter Estimate	SE	Wald Chi-Squared	*P* > Chi-Squared
Intercept	11.10	4.17	7.09	0.008
T/2H if <1.2, otherwise 1.2	−8.76	3.08	8.09	0.004
Wheelbase	−0.05	0.02	5.66	0.017
Gender	0.84	0.31	7.22	0.007
Occupants	0.39	0.14	7.11	0.008

Note. Model Fit: $-2 \log L\ \chi^2 = 25.9$, $df = 4$ ($P = .0001$). n = 543; 62 cases were excluded because of missing observations, mostly because of tinted windshields.

TABLE 4—Stepwise Regression of Speed at Rollover Sites at Same Time of Day and Same Day of Week and with Traffic in the Same Direction

Variable	Parameter Estimate	SE	F	*P*
Intercept	5.45	2.17	6.29	.0125
Average speed	1.02	0.02	1991.65	.0001
Driver age	−0.04	0.03	3.00	.0840
Weight/horsepower	−0.19	0.07	7.62	.0060
$R^2 = 0.80$				

Results

The criteria for inclusion were met by 554 comparison vehicles at 51 rollover sites. Table 1 compares the rollover and exposure vehicles by static stability (T/2H). Rollover is almost 3 times that expected from exposure among vehicles with T/2H less than 1.10 and nearly 1.5 times that expected among vehicles with T/2H of 1.10 through 1.19.

The odds of rollover, adjusted for other factors, were assessed by stepwise logistic regression (Tables 2 and 3).[12] As indicated in Table 3, only T/2H less than 1.2 was correlated to rollover. As T/2H increases up to 1.2, the odds of rollover decline, and there is no significant correlation above 1.2. In addition, the odds of rollover were increased by the number of occupants and by a female driver and were lower for vehicles with a longer wheelbase. Weight/horsepower, average T/2H, and age of driver were not significantly related to rollover. Average T/2H was included to assess the potential effect of concentration of certain types of vehicles by site.

The extent to which less stable vehicles are driven at higher or lower speeds than other vehicles is addressed in Table 4. Observation showed that speeds among the vehicles at a given site were similar, but not necessarily near the speed limit at the site. For example, Figure 1 shows the distribution of speed at two sites with a 25 mph speed limit. This has been called contextual effect, that is, something about the context of a situation affects the behavior of people or other phenomena.[13]

Therefore, a stepwise regression of speed was done, with average speed at the site entered in the model to capture the contextual effect. Average speed at the site was by far the strongest predictor of speed. In addition, younger drivers were driving faster, and vehicles with lower weight-to-horsepower ratios were driven faster than would be expected from the average. Stability, wheelbase, and gender were not significantly correlated to speed, when other factors at sites where vehicles rolled over were controlled for.

Conclusions

As found in previous research, the further T/2H is below 1.2, the greater the odds of rollover. The addition of occupants to vehicles increases the center-of-

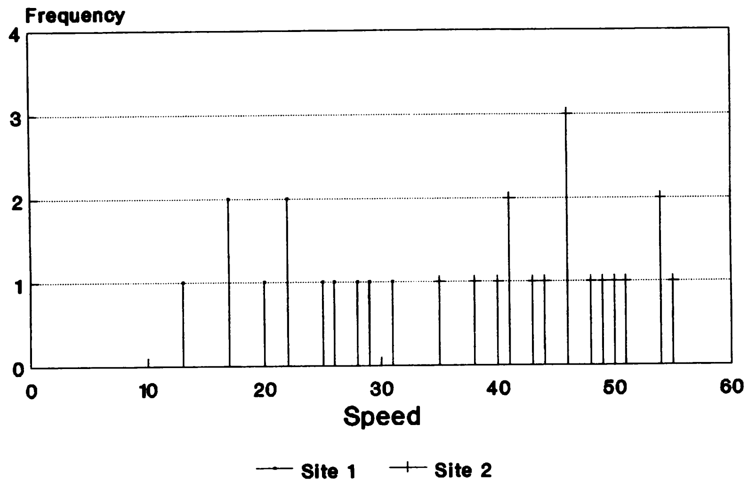

FIGURE 1—Automobile speeds at two Connecticut sites with 25 mph limit.

gravity height and makes the vehicles less stable. Therefore, the more passengers in a vehicle, the greater the odds of rollover.

Although the speed of the vehicles that rolled over was not known in most cases, and was not included in the analysis of speed, the correlates of speed of vehicles at the same times and places of rollovers indicate that vehicles of lower stability are not driven faster on average. Therefore, speed cannot be a confounder of the effect of stability on rollover. Vehicles that are heavier relative to horsepower are driven more slowly and have lower rollover, suggesting that speed has an effect independent of stability.

The apparent contextual effect of speed and the lack of correlation of stability and speed suggest that drivers of low-stability vehicles are influenced by whatever contextual factors are affecting speed for all drivers. To the extent that the lower stability vehicles are incapable of turns, emergency or otherwise, at the prevalent speed, the vehicles are more likely to roll over in situations where the drivers perceive the need for a turning maneuver.

Rollover could be reduced substantially if cars, pickup trucks, vans, and utility vehicles were manufactured with a static stability of 1.2 or greater. Given the effect that an increased number of occupants has on rollovers, the greater the number of seating positions there are, the greater the need is for higher stability. The contextual effect on speed is worthy of research on contextual factors that could be modified to reduce speeds where appropriate. □

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